Climate Change and Western Australian Aquatic Ecosystems

Impacts and Adaptation Responses

This report card summarises our current knowledge of the impacts of climate change on Western Australian aquatic ecosystems, highlighting key knowledge gaps and adaptation responses.

“Climate change is happening now. WA’s environment is highly vulnerable to climate change and the State’s natural resources, biodiversity, industry and human health are at risk, and in some instances are already being affected.”

State of the Environment Report: Western Australia 2007

Key points:

> Southwestern WA is a global biodiversity hotspot and is recognised as one of the most vulnerable regions to the effects of climate change.

> The warming and drying climate in the southwest has many freshwater species and ecological communities already at the limits of survival. Reduced rainfall, runoff and declining groundwater levels combined with increasing evapotranspiration have resulted in reduced river flow, disconnected river pools, drying wetlands, and loss of unique cave fauna.

> Reduced flows and rising sea levels in WA have changed habitat distribution and quality in estuaries and rivers, and have the potential for irreversible consequences in coastal freshwater wetlands.

> Adaptation options seek to increase the resilience of aquatic ecosystems, through reducing adverse impacts of human activities and managing the risks from climate change.
KNOWLEDGE OF WA WETLANDS AND WATERWAYS

Western Australia is a vast and sparsely populated state. The environmental conditions vary greatly from temperate southern areas to tropical north and from coastal plains to inland deserts. There is great diversity in wetlands and waterways, few of which have been extensively researched. Increasing the knowledge of these systems will enable better management.

Northern WA
> Low to moderate level of understanding of some systems (e.g. Ord, Fitzroy, Pilbara).
> Poor agreement between climate change models. Predictions often not consistent with recent climate observations.
> Included in CSIRO Northern Australia Sustainable Yields Project.

South-West
> Moderate to High level of understanding of existing systems.
> Moderate to High confidence in predictions of impacts of climate change (models consistently predicting drying trend).
> Included in CSIRO South-West Western Australia Sustainable Yields Project.

Rest of the State
> Moderate level of understanding of some systems, poor for most others.
> Low confidence in predictions of impacts of climate change.
> Sustainable yields projects needed.

INCREASING RESILIENCE
> Reduce human demand for water.
> Increase sustainable water and land use practices.
> Reduce input of pollutants.
> Maintain hydrological connectivity between river networks.
> Reduce competition and disturbance from introduced fauna and flora.
> Maintain appropriate fire regimes.
> Increase connectivity between natural areas.

CLIMATE CHANGE

According to Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report in 2007, emissions of greenhouse gases resulting from human activity are a major driver of climate change. Immediate and vigorous international effort is required to reduce global greenhouse gas emissions in order to minimise future climate change.

Despite mitigation efforts, some level of ecosystem change is certain due to the greenhouse gases already in the atmosphere.

Adaptation options for WA aquatic ecosystems seek to manage this transition by increasing resilience and minimising risks from climate change impacts.

OTHER STRESSORS

In addition to climate change, WA wetlands and waterways are subject to a number of other stress factors including competing land uses, vegetation clearing, drainage, water abstraction, salinisation, pollution, and introduced pests, weeds and diseases.

Adaptation to climate change will need to consider these existing management concerns.

Removing or reducing these other stress factors and/or their impacts will increase the resilience of the ecosystems, enabling them to better adapt to climate change.

LEGEND

CSIRO Sustainable Yields Project Boundaries
## WHAT IS HAPPENING?

### South Western WA

**Temperature**
- Temperature has increased by 0.4-0.8°C over last 40 years.
- Temperature will increase by 0.5 - 2.0°C by 2030, compared to 1960-1990 baseline.

**Rainfall**
- Rainfall has reduced by up to 50mm/10 years between 1970-2010. Reduction of 10-15% in the northern part of the SW is the largest reduction in Australia.
- Seasonality has changed with less rain in autumn and early winter, and slightly more rain in summer.
- Rainfall will reduce by 2-14% (median 8%) by 2030, compared to 1975-2007 baseline. Southwest is predicted to experience some of the largest reductions in rainfall in all of Australia.

**Runoff**
- Average stream flow into southwest dams during 1975-2010 was approximately 50% less than pre-1975 average.
- Runoff will reduce by 10-42% (median 25%) by 2030, compared to 1975-2007 baseline.

**Groundwater**
- Variable trends have been observed in groundwater levels across southwest.
- Groundwater levels in Perth (Gnangara Mound) have declined by up to 6 m during 1979-2005, with up to 4 m of this being due to reduced rainfall.
- Groundwater levels in areas of high extraction are projected to be most affected by a continuation of the hotter and drier climate. Extractive yields may decrease by a third to a half in some areas.

**Sea level**
- In Fremantle, sea level has risen on average by 1.54 mm/year for the past 100 years but by 5 mm/year for the past 10 years.
- Median future climate scenarios predict 100 mm increase from 1990 to 2030.

**Extreme events**
- While extreme weather events such as summery cyclones have occurred, it is difficult to attribute these events to climate change.

### Northern WA (*predictions variable between different climate change models)*

**Temperature**
- In most areas of the Kimberley temperature has increased by up to 0.6°C, however in some areas it has dropped by 0.2°C over the last 40 years. Temperature in the Pilbara has increased by 0.2-0.8°C.
- Northern WA is expected to become warmer with more hot days and less cold nights.*

**Rainfall**
- Contrary to anticipated trends, significantly elevated rainfall has occurred in the Canning Basin and West Kimberley in recent decades. This may in part be due to raised levels of aerosols from particulate pollution over Asia.
- Modelling predicts that rainfall will reduce slightly in the Kimberley by 2030 compared to 1930-2007 baseline.*

**Runoff**
- In line with elevated rainfall described above, increased runoff has been recorded in the Pilbara, Canning Basin and West Kimberley in recent decades.
- Modelling of runoff derived from temperature and rainfall predictions suggests little change in the Kimberley by 2030 compared to 1930-2007.*

**Groundwater**
- Collected data is insufficient to identify long term trends.
- Insufficient data and groundwater models.

**Sea level**
- In Broome, sea level has risen on average by 2.23 mm/year between 1966-2003 but by 7.1 mm/year between 1991-2010.
- Median future climate scenarios predict 100 mm increase from 1990 to 2030.

**Extreme events**
- Northern WA naturally experiences high seasonal and inter-annual variability in weather making it difficult to distinguish extreme events.
- Insufficient data.

### Rest of the State - Further data collection and modelling required

References for the above table are provided in Climate Change Impacts and Adaptation Strategies for Western Australian Aquatic Ecosystems report. See back cover for more details.
### Common to all Aquatic Ecosystems (South-West)

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<td></td>
<td>&gt; Reduction in quantity of water entering aquatic ecosystems via rain, surface runoff or groundwater inflow.</td>
<td>&gt; Overall reduction in biodiversity.</td>
<td>&gt; Model hydrology of critical wetlands, waterways and aquifers (e.g. Ramsar sites and threatened communities).</td>
<td>&gt; Evaluate and prioritise aquatic ecosystems for conservation measures.</td>
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<td>&gt; Less internal water movement. Increased evapotranspiration due to higher temperatures.</td>
<td>&gt; Progressive change from aquatic to terrestrial species and habitats.</td>
<td>&gt; Determine limits of tolerance of vulnerable species and communities.</td>
<td>&gt; Incorporate climate change threats into recovery/other management plans.</td>
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<td></td>
<td>&gt; Reduction in extent, depth and volume of wetlands and waterways. Permanent systems becoming more seasonal and seasonal systems becoming episodic or disappearing.</td>
<td>&gt; Local shifts in species composition. Sensitive species may be lost due to changes in water availability, temperature, and water quality. Increase in temperature tolerant species (e.g. Spangled Perch), existing pests (e.g. Gambusia) and exotic warm-water species (e.g. cane toads).</td>
<td>&gt; Identify susceptibility of species to changes in lifecycle triggers.</td>
<td>&gt; Promote to the community the necessity of environmental water requirements as a key climate change adaptation.</td>
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<td>&gt; Increased average and maximum water temperatures. Changes in rates of chemical processes and equilibria.</td>
<td>&gt; Potential extinctions of endemic species unable to cope with the rate of change, especially those with poor dispersal mechanisms or in habitats affected by human activity.</td>
<td>&gt; Research the effectiveness and risks of translocations and altered reserve design.</td>
<td>&gt; Consider translocations of fauna to habitats with suitable environmental ranges.</td>
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<td>&gt; Altered water regime (e.g. delayed onset of winter filling, premature drying, extended dry spells, unseasonal rainfall due to cyclonic activity).</td>
<td>&gt; Plant productivity will be affected by changes in temperature, water quality and higher CO₂ concentrations.</td>
<td>&gt; Research response of nuisance and pest species to climate change.</td>
<td>&gt; Promote connectivity between remnant aquatic habitats and maintain or create refuges.</td>
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<td>&gt; Salinisation of coastal aquifers, wetlands and waterways due to marine intrusion, inundation, or salt water wedge.</td>
<td>&gt; Potential increase in algal blooms, anoxia and fish kills. Potential increase in midges and mosquitoes.</td>
<td>&gt; Identify changes in ecosystem functions and services in response to altered hydrological and temperature regimes.</td>
<td>&gt; Clarify institutional roles and management responsibilities.</td>
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<td>&gt; Changes to water quality due to changing quantity and quality of inflows.</td>
<td>&gt; Potential disruption of reproductive cycles of biota. Changes to seasonal migration triggers. Depletion of seed and egg banks.</td>
<td>&gt; Identify systems at risk of acidification.</td>
<td>&gt; Improve availability of information to all stakeholders.</td>
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<td>&gt; Acidification through oxidation of acid sulphate soils (due to reducing water levels) and associated release of metals.</td>
<td>&gt; Altered cycling of nutrients and carbon.</td>
<td>&gt; Implement technology and engineering solutions to sustain threatened ecosystems e.g. oxygenation, excavation of pools.</td>
<td>&gt; Incorporate climate change adaptation into land use planning.</td>
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<td>&gt; Increased fire risk.</td>
<td>&gt; Potential loss of freshwater habitat in favour of brackish/saline habitat in coastal areas.</td>
<td>&gt; Increase resilience by reducing other stressors.</td>
<td>&gt; Promote efficient water use and reuse.</td>
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</table>

The impacts and adaptation options summarised above apply to the majority of wetlands and waterways in the south-west of WA. In addition to these, there are more system specific impacts and adaptation options for different types of wetlands and waterways summarised on the following page.
<table>
<thead>
<tr>
<th>ANTICIPATED PHYSICAL AND CHEMICAL CHANGES</th>
<th>POTENTIAL ECOLOGICAL CONSEQUENCES</th>
<th>ADDRESSING KNOWLEDGE GAPS</th>
<th>KEY ADAPTATION OPTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wetlands - Groundwater Dependent</strong></td>
<td>▶ Complete loss of surface expression of groundwater in some areas but increase in others. ▶ Potential loss of groundwater-dependent species (e.g., Salamander fish) and communities (e.g., thrombolites).</td>
<td>▶ Research tolerance of communities to increased duration and frequency of dry periods and change in water source.</td>
<td>▶ Reduce groundwater abstraction and promote aquifer recharge. ▶ Facilitate new wetland formation where groundwater levels rise.</td>
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<tr>
<td><strong>Wetlands - Surface Water Dependent</strong></td>
<td>▶ Potential permanent loss of surface water particularly in shallow/seasonal systems. ▶ Changes in water quality. Potential increase in quality due to reduced inputs. Potential decline in quality due to increased evaporation.</td>
<td>▶ Loss of habitat and consequent loss of biodiversity specific to surface water dependent wetlands (e.g., palusplains on Swan Coastal Plain). ▶ See table “Common to all Aquatic Ecosystems (South-West)” on previous page.</td>
<td>▶ Reduce surface water abstraction and other stressors. ▶ Catchment management where terrestrial vegetation water use is reduced e.g. via thinning.</td>
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<tr>
<td><strong>Caves and other Subterranean Aquatic Ecosystems</strong></td>
<td>▶ Complete loss of water from the caves and other subterranean ecosystems (e.g., fractured rock and porous substrates). ▶ Potential loss of aquatic cave communities ▶ Extinction of some stygofauna species.</td>
<td>▶ Map subterranean ecosystems. ▶ Understand ecology in relation to climate change. ▶ Improve taxonomy and distribution information for stygofauna.</td>
<td>▶ Reduce groundwater abstraction and promote aquifer recharge.</td>
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<td><strong>Rivers</strong></td>
<td>▶ Altered flow regime and reduced flow. Loss of perennial flow, deep pools and connectivity between them. ▶ Changes to water quality due to less fresh water input and longer stagnant periods. Reduced dissolved oxygen in pools. ▶ Loss of aquatic refuges in headwater streams in summer. ▶ Decrease in connectivity and increase in barriers to dispersal. ▶ Loss of cold water species. ▶ Changed distribution and range of native and introduced species. Potential loss of endemic freshwater species (e.g., Balston’s Pygmy Perch).</td>
<td>▶ Determine importance of groundwater in maintaining stream flow. ▶ Identify most ecologically valuable areas with perennial flow. ▶ Map locations of deep pools and ground truth existing/future barriers to dispersal. ▶ Identify changes in distribution and range of species.</td>
<td>▶ Revegetate along northern banks to reduce temperature. ▶ Promote connectivity (e.g., fish ladders). ▶ Retrofit existing drainage structures to supplement river flows. ▶ Reduce other stressors (e.g., salinity).</td>
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<td><strong>Estuaries</strong></td>
<td>▶ Altered hydrodynamics, increased marine influence, altered bar dynamics, reduced river flow, reduced flushing, deposition of river sediments, upstream movement of salt-wedge, increased stratification, decreased oxygenation, changing foreshore stability. ▶ Significant changes in habitat distribution (increased marine, decreased freshwater). ▶ Decreased habitat quality of estuarine reaches (e.g., deoxygenation, increased algal blooms).</td>
<td>▶ Identify limits of tolerance for vulnerable estuarine species and communities.</td>
<td>▶ Manage sand bar dynamics. ▶ Manage salt water intrusion. ▶ Clarify institutional roles and responsibilities for estuary management.</td>
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</table>
### Common to allAquatic Ecosystems (Northern WA)

#### Key Stressors:
- Increased temperature
- Rising sea level (coastal areas)

#### Potential Future Stressors:
- Reduced/Increased rainfall
- Reduced/increased runoff
- Changes to seasonality

#### Anticipated Physical and Chemical Changes

- Increased average and maximum water temperatures. Changes in rates of chemical processes and equilibria. Increased evapotranspiration due to higher temperatures.
- Salinisation of coastal aquifers, wetlands and waterways due to marine intrusion, inundation, or salt water wedge.
- Current climate modelling does not predict significant changes in rainfall, runoff or seasonality in Northern WA, however this may change in the future as models are refined. Significant changes in these stressors would potentially result in following:
  - Changes in quantity of water entering a quatic ecosystems.
  - Changes in extent, depth and volume of aquatic ecosystems.
  - Changes in water regimes (e.g. alterations in seasonality).
  - Changes in water quality.
  - Acidification through oxidation of acid sulphate soils and associated release of metals.
  - Increased fire risk.

#### Potential Ecological Consequences

- Local shifts in species composition. Sensitive species may be lost due to changes in temperature and water quality. Increase in temperature may give competitive advantage to temperature tolerant species (e.g. cane toads).
- Change in sex ratio of species such as turtles and crocodiles as a result of increased temperature will reduce breeding capacity.
- Increase in pool anoxia and fish kills.
- Loss of freshwater habitat in favour of brackish/saline habitat in coastal areas (e.g. replacement of freshwater floodplain wetlands with salt marshes).
- Potential extinctions of endemic species unable to cope with the rate of change, especially those with poor dispersal mechanisms or in habitats affected by human activity.
- Altered cycling of nutrients and carbon.
- Significant changes in ‘potential future stressors’ would potentially result in following:
  - Changes in biological productivity that is strongly linked with hydrology.
  - Progressive change from aquatic to terrestrial species and habitats or vice versa subject to loss/gain in rainfall and runoff.
  - Changes in range and number of mosquitoes due to availability of water.

#### Addressing Knowledge Gaps

- Refine climate change modelling for northern Australia and then re-assess risks to aquatic ecosystems.
- Implement field research to investigate relationships between ecology of streams and hydrology (flow) classification established by Kennard et al. 2010.
- Determine limits of tolerance of vulnerable species and communities.
- Research response of nuisance and pest species to climate change.
- Research the effectiveness and risks of translocations as an adaptation option.

#### Key Adaptation Options

- Incorporate climate change threats into management plans.
- Promote to the community the necessity of environmental water requirements as a key climate change adaptation.
- Consider translocations of fauna to habitat with suitable temperature range.
- Clarify institutional roles and management responsibilities.
- Incorporate climate change adaptation into land use planning.
- Implement technology and engineering solutions to sustain threatened ecosystems where appropriate (e.g. barriers to marine inundation).
- Increase resilience by reducing other stressors.
- If in the future significant changes are predicted in the ‘potential future stressors’, the associated additional knowledge gaps will need to be determined and addressed.
This report card summarises present knowledge of impacts of climate change on Western Australian aquatic ecosystems and identifies knowledge gaps and adaptation options. The report card is based on a more comprehensive report called Climate Change Impacts and Adaptation Strategies for Western Australian Aquatic Ecosystems, developed in consultation with the contributors listed above during and after Climate Change and WA Wetlands and Waterways Symposium 2010. The project received funding from the Department of Water, Government of Western Australia (NRM Program), National Climate Change and Adaptation Research Facility and was supported by Murdoch University and the Department of Environment and Conservation.

Recommended reference for this publication is:

References used in preparation of this report card are detailed in the report Climate Change Impacts and Adaptation Strategies for Western Australian Aquatic Ecosystems, found at www.nccarf.edu.au/water/node/29 or email J.Chambers@murdoch.edu.au